Influence of an Indoor Small Cell on the Human Exposure to Radio Frequency Electromagnetic Fields

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SUMMARY

In this study, the impact of the deployment of a small cell in a train and an office on the total exposure (both downlink and uplink) of a mobile-phone user to radio frequency (RF) electromagnetic fields (EMF) was studied for two technologies. To determine the exposure, the total RF-EMF dose absorbed by the user was calculated, using measurements of the received and transmitted powers of the mobile phone. For GSM, a decrease in exposure by a factor 60 can be achieved, while the reduction for UMTS is limited. The presented framework can be used for any exposure scenario, featuring any number of technologies, base stations, users, and duration.

INTRODUCTION

Recent advancements in mobile technologies include the development of miniature base stations (small cells), specifically designed for the enhancement of the coverage and capacity of a mobile service in a small indoor environment (e.g., office, home, train, etc.). Generally, small cells are installed in areas readily accessible to the users of the mobile service. However, the impact of the small cell (SC) on the users' exposure to radio-frequency (RF) electromagnetic fields (EMF) remains uncertain.

The objective of this study was to quantify the effect of the small cell on the RF-EMF exposure of a mobile-phone user in an indoor environment, using the absorbed-dose framework presented in Ref. [1], in which the contributions of the base station (a far-field source) and the mobile phone (a near-field source) are combined to determine the total whole-body exposure of the user, taking into account the total time spent by the subject in the environment (exposure time) and the total time the subject uses his mobile phone (MP) (use-time).

MATERIALS AND METHODS

In this study, a small cell was installed in two indoor environments, i.e., an *office* corridor (approximately 60 m long, of which 18 m was in line-of-sight of the small cell installed at one end of the corridor) and a *train* car (15 m, line-of-sight of the small cell installed at one end of the car), each with a different technology, i.e., Universal Mobile Telecommunications System (UMTS) at 2100 MHz, and Global System for Mobile Communications at 1800 MHz (GSM1800), respectively.

Using the framework of Ref. [1], measurements of the received (*RSSI* – Received Signal Strength Indication) and transmitted (P_T) power of a mobile phone (MP) were converted into the total ***whole-body averaged dose, D*** (in J/kg), absorbed by the subject during an exposure time of 1 h as a function of the mobile-phone use-time (t_{use}) as well as the output power of the small cell (P_{SC}). With the MP either connected to a macrocell (MC) or a small cell (SC) base station, a comparison could be made between the two connection scenarios in both environments.

In the static environments (i.e., *office-MC, office-SC,* and *train-SC*) the *RSSI* and P_T values of the MP (Nokia N95, with Field Test Display app) were measured along the length of the environment. However, in the dynamic *train-MC* scenario, the circumstances changed continuously, so as to obtain an accurate idea of the average received and transmitted powers, the *RSSI* and P_T values of an MP (HTC Explorer, with Azenqos app) were logged during the train ride (while staying at the same position), using numerous one-minute phone calls.

RESULTS

In Fig. 1, the whole-body averaged dose (calculated as in Refs. [1] and [2]) absorbed during one hour in the considered scenarios is shown as a function of t_{use}. Generally, the doses are lower when using UMTS (office) instead of GSM1800 (train). This is mainly due to the lower output power of the MP in UMTS mode, which can be seen from the fact that the contribution of the base stations (MC for the MC scenarios, and both MC and SC for the SC scenarios) (downlink) to the exposure remains dominant up to higher t_{use} (e.g., up to a t_{use} of 1 s for UMTS compared to 10^{-4} s for GSM1800 in the MC scenarios, see Fig. 1).

It is also clear that the presence of an SC does not always lead to a reduction of the human exposure in the considered environments. Rather, the exposure reduction or *increase* depends on both P_{SC} and t_{use}. E.g., for a P_{SC} of 100 mW, the contribution of the SC (downlink) to the exposure can be several orders of magnitude higher than the total exposure (downlink + uplink) in the MC scenarios; in the worst-case scenario (t_{use} = 0 s), the train-SC dose is a factor 5000 higher than the train-MC dose, and the office-SC dose a factor 30 higher than the office-MC dose (Fig. 1).

The lines shown in Fig. 2 represent the boundaries between increasing and decreasing the user's whole-body exposure when deploying an SC in the considered environments; the surfaces below the curves indicate the regions where deployment of the SC in the considered scenario would *not* be beneficiary for the user's exposure, i.e., t_{use} is too low and/or P_{SC} is too high. As the curve for UMTS lies two orders of magnitude above the GSM curve (Fig. 2), there are much fewer t_{use} - P_{SC} combinations for which installing a UMTS SC would effectively reduce the exposure, and the magnitude of the impact will be smaller than for GSM1800. E.g., considering a P_{SC} of 1 mW and a t_{use} of 1 minute (realistic values) (Fig. 1), $D_{office\text{-}SC}$ = 2.8 µJ/kg and $D_{office\text{-}MC}$ = 8.0 µJ/kg (hence, the SC reduces the exposure by a factor 3) and $D_{train\text{-}SC}$ = 0.3 mJ/kg and $D_{train\text{-}MC}$ = 18.9 mJ/kg (a reduction by a factor 60).

CONCLUSIONS

The impact of the use of an indoor small cell (SC) on a mobile phone user's total exposure to radio-frequency (RF) electromagnetic fields (EMF) is assessed in two indoor scenarios for UMTS and GSM at 1800 MHz technologies. It is found that deploying an SC could reduce the user's RF-EMF exposure, although the magnitude of the reduction depends heavily on the mobile-phone use-time and the SC output power. Furthermore, because of the inherently lower mobile-phone output powers when using UMTS technology compared to GSM, the magnitude of the impact on the RF-EMF of installing a UMTS SC is expected to be smaller than deployment of a GSM SC. It should also be noted that other factors further influence the impact of the SC on the total exposure, i.e., the initial MC coverage, the size of the environment and the amount of SCs to be deployed, and the amount of mobile-phone users in the environment; this will be the topic of future research.

ACKNOWLEDGMENTS

This work has been carried out within the iMinds project ‘Railway Applications Integration and Long-term networkS (RAILS)', co-funded by iMinds, a research institute founded by the Flemish Government in 2004, and the involved companies and institutions, and supported by IWT (agency for Innovation by Science and Technology). W. Joseph is a Post-Doctoral Fellow of the FWO-V (Research Foundation–Flanders).

REFERENCES

1. Lauer O, Frei P, Gosselin M-C, Joseph W, Röösli M, Fröhlich J. 2013. *Combining near- and far-field exposure for an organ-specific and whole-body RF-EMF proxy for epidemiological research: a reference case*. Bioelectromagnetics 34:366–74.
2. Aerts S, Plets D, Verloock L, Martens L, Joseph W. 2013. Assessment and comparison of total RF-EMF exposure in femtocell and macrocell base station scenarios. Radiat Prot Dosim [E-pub ahead of print].

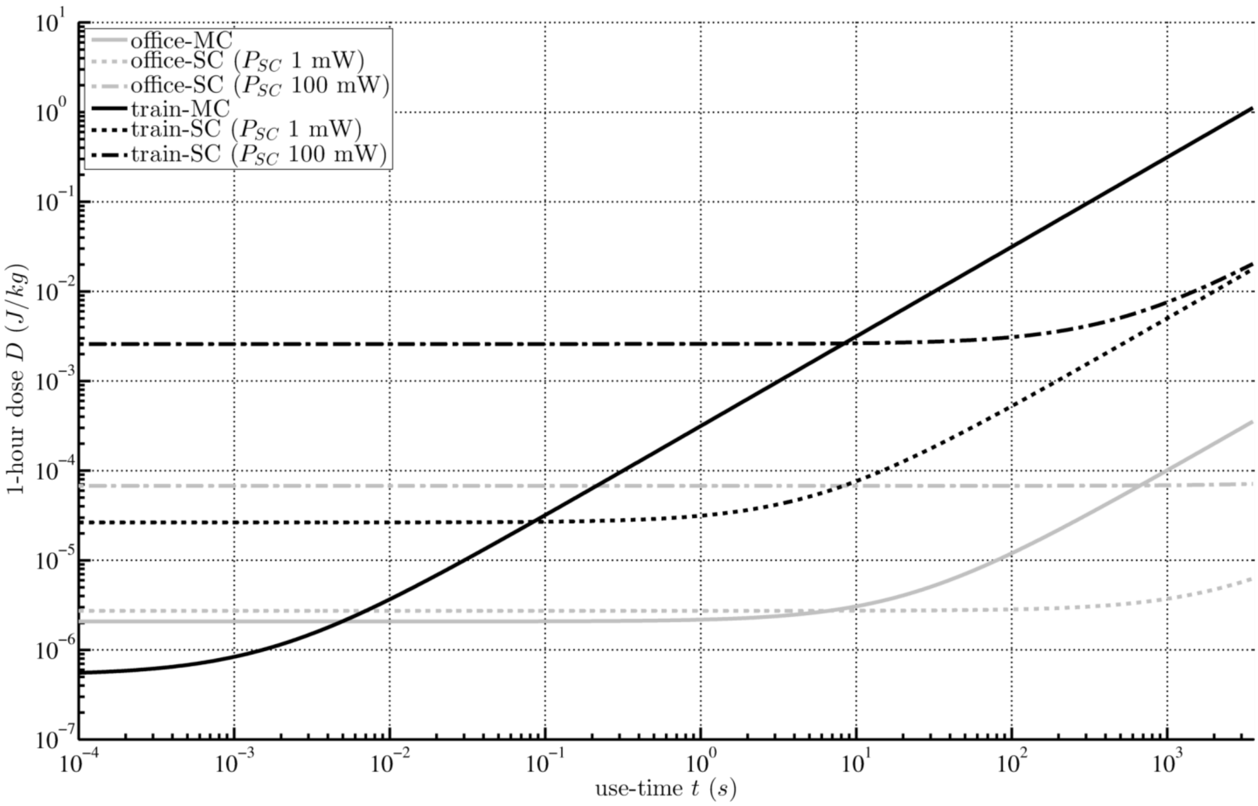

Figure 1: One-hour whole-body averaged doses absorbed by a person as a function of the time spent using his or her mobile phone, connected to a macro cell (full lines) or a small cell installed in the environment (dotted or dash-dot lines, representing small-cell output powers P_{SC} of 1 and 100 mW, respectively),when either in an office (grey lines) or a train (black lines).

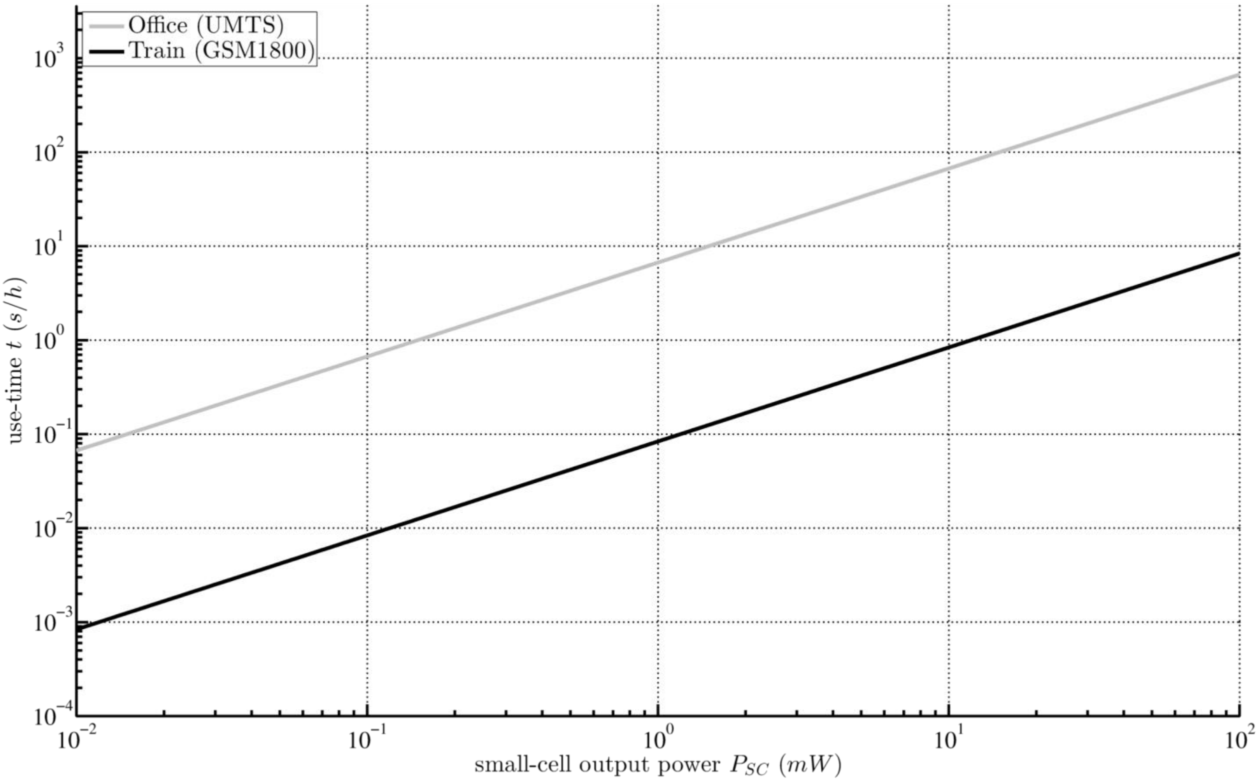

Figure 2: Use-time versus the output power of the small cell, indicating the boundary for which deployment of a small cell in the considered environment is no longer beneficiary for the user's exposure (region below the curves) for the specific technology (UMTS in the office corridor, GSM1800 in the train car).